Determining the Martian Radiation Environment – the Radiation Assessment Detector (RAD) on Mars Science Laboratory (MSL). R.F.Wimmer-Schweingruber[1], D. M. Hassler[2], C. Zeitlin[2], S. Böttcher[1], C. Martin[1], J. Andrews[2], E.Böhm[1], G.Weigle[3], D. Brinza[4], A. Posner[5,8], S. Burmeister[1], M. Epperly[3], L. Seimetz[1], G. Reitz[6], O Kortmann[1,]7, J. Köhler[1], B. Ehresmann[1], K. Neal[2], S. Rafkin[2], J. Peterson[2], Y. Tyler[3], K. Smith[3], M. Bullock[2], and F. Cucinotta[7]. [1]Institute for Experimental and Applied Physics, Christian-Albrechts-University Kiel, Leibnizstr 11, 24098 Kiel, Germany (wimmer@physik.uni-kiel.de), [2]Southwest Research Institute, 1050 Walnut St., 80302 Boulder, CO (hassler@swri.org), [3]Southwest Research Institute, 6220 Culebra St., 78228 San Antonio, TX, [4]NASA Jet Propulsion Laboratory, Pasadena, CA, [5]NASA Headquarters, Washington, DC, [6]German Aerospace Center, Institute for Aerospace Medicine, Cologne, Germany, [6]now at Space Science Laboratory, UC Berkeley, CA, [7]NASA Johnson Space Center, Houston, TX, [8]currently at NASA Goddard Space Flight Center, Greenbelt, MD

Introduction: The Radiation Assessment Detector (RAD) on NASA's Mars Science Laboratory (MSL) mission was designed to characterize the broad spectrum of energetic particles on the surface of Mars, including the galactic cosmic rays (GCRs), solar energetic particles (SEPs), and secondary charged and neutral particles created in the Martian atmoshpere and regolith (Fig. 1). The radiation environment on Mars is a key life-limiting factor which directly affects habitability and the ability to sustain life.

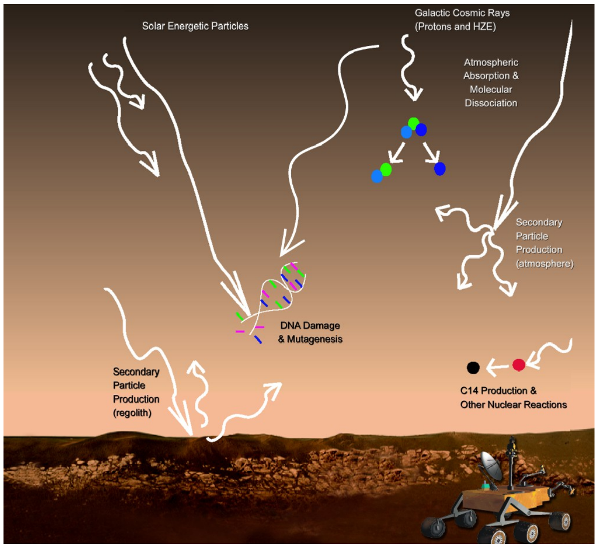

Fig. 1: The radiation environment on Mars is determined by the GCR, SEPs, and secondary particles formed by their interaction in the atmosperhe and regolith.

RAD combines charged particle and neutron detection capability over a wide dynamic range in a compact, low-mass instrument. The RAD instrument consists of the RAD Sensor Head (RSH) and the RAD Electronics Box (REB). The RSH consists of a solid state detector telescope with three silicon PIN diodes for charged particle detection, and a thallium doped Cesium Iodide (CsI) scintillator, an organic plastic scintillator (BC432m) and anti-coincidence shield for neutral particle detection, as well as the associated front-end read-out electronics. The REB includes three circuit boards, an analog board with a novel mixed-signal ASIC and a control FPGA, a digital board with a second FPGA to communicate with the rover, and a power supply and sleep-control electronics board which enables autonomous operation, independent of the rover. RAD is a highly capable and highly configurable instrument that paves the way for future compact energetic particle detectors in space.

Measuring neutral particles: It is not easy to measure neutral (uncharged) particles because they do not ionize directly in common detector materials. RAD combines a high-Z scintillator (CsI) and a hydrogen-rich plastic scintillator (BC-432m) which have different response properties to neutrons and gamma rays (Fig. 2). RAD uses a statistical inversion technique to determine the flux of neutrons and gammas on the Martian surface. Calibration data have been analyzed and show that this method works [1].

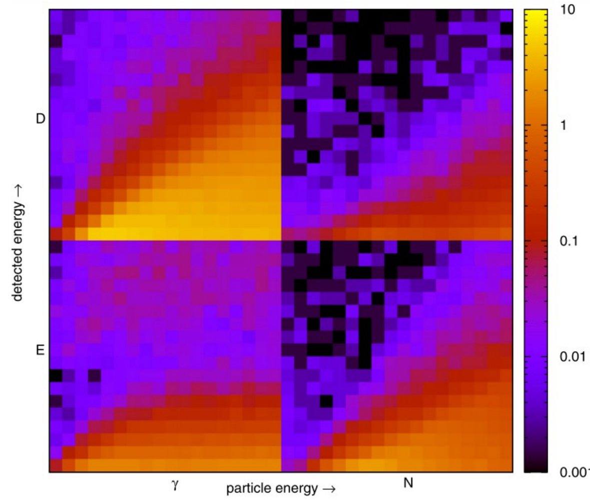

Fig 2: RAD geometric factor for neutrons (right) and gammas (left) in CsI (top) and BC432m (bottom).From [1].

The response of the CsI scintillator is temperature dependent, but can be accurately characterized (Fig 3), allowing for a good determination of the neutral parti-

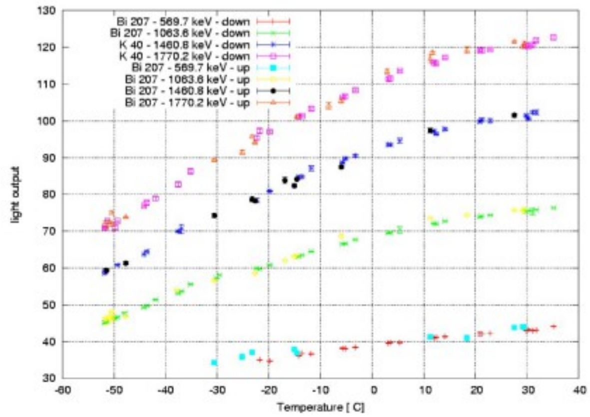

Fig. 3: The temperature dependence of the CsI scintillator can be accurately characterized.The different curves show the response of CsI to various lines of 207Bi and 40K.

cle dose rate on Mars. There neutrons contribute significantly to the total dose [2].

Measuring charged particles: Similarly, RAD has also been calibrated for heavy ions at the HIMAC facility in Japan. The calibration of ions is relatively straightforward, the one difficulty lies in the incomplete conversion of ionization losses to light, the so-called quenching of the signal. This effect must be considered in detail in the final analysis on ground, the on-board classification scheme accounts for this effect in an approximate manner.

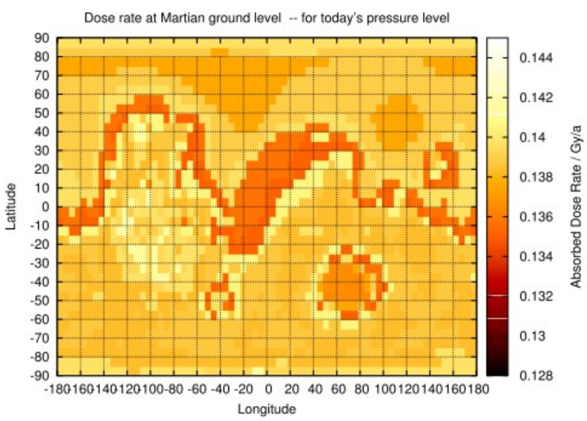

Fig. 4: Absorbed dose rates on the Martian surface for present-day conditions. These were different and higher in the past when Mars had a thicker atmosphere.From [2].

Contributions to total dose and dose rate: The total dose (due to neutral and charged particles) has been modeled for the present-day and past environments with higher atmospheric pressures [2]. Fig. 4 shows present-day dose rates which obviously show a dependence on height, which is a consequence of the pressure-dependence of the generation of secondary particles in atmosphere and regolith. The radiation environment in the past was likely quite different than today. Not only was the dose rate higher, but the admixture of the different contributing particle species was also different. Fig. 5 shows calculations by [2] on the altitude dependence of the various componentes for an enhanced atmospheric pressure (factor 25 relative to todays pressure).

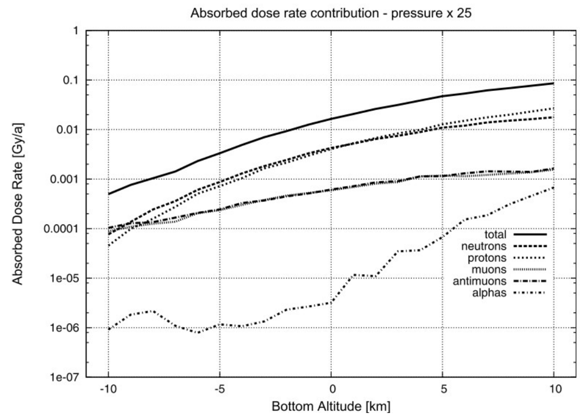

Fig. 5: Altitude dependence of the various particle species contributing to the dose rate at the Martian surface for an atmospheric pressure 25 times todays. From [2].

Initial cruise data and conclusions: RAD has been acquiring data since December 6, 2011, and will continue to do so en route to Mars. We will present initial data and a consistency analysis. RAD provides a good estimate of the dose that astronauts will experience on their way to and on Mars, thus preparing manned exploration of our neighbor planet.

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References: [1] Köhler J., Ehresmann, B., Martin, C., Böhm, E., Kharytonov, A., Kortmann, O., Zeitlin, C., Hassler, D. M., and Wimmer-Schweingruber, R. F. (2011) *NIMB*, *269*, 2641–2648. [2] Ehresmann B., Burmeister, S., Wimmer-Schweingruber, R.F., Reitz, G. (2011) *JGR*, *116*, A10106.